NDE

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NONDESTRUCTIVE EVALUATION PROGRAM AT THE NATIONAL BUREAU OF STA

Introduction. Today, many material failures are prevented thanks to a system of test methods that detects flaws and defects in materials before the failures occur—in fact, before the materials are put into service. Called "nondestructive evaluation (NDE)," the system is potentially applicable to inspection of such high technology products as nuclear reactors and supersonic aircraft as well as to inspection of more consumer-oriented products such as pacemakers and parts of surgical implants.

Actually, NDE is not a single method, but rather a name used to describe a variety of techniques that can be used to examine materials without destroying or damaging the material during the examination procedure. Some of these methods, x-radiography for example, have been used for many years. Others, such as neutron radiography and acoustic emission, are just now coming into wider use as NDE methods.

Cover: A gamma radiograph of the Liberty Bell taken before it was moved to its Bicentennial location. (Photo courtesy Eastman-Kodak Co.)

Despite the increasing use of NDE methods for practical purposes, there are definite needs to improve the measurement methods and to relate measurements to the actual performance of the material. The National Bureau of Standards has established a Nondestructive Evaluation Program to assist industry and government agencies in improving the reliability of materials and structures through standardized NDE measurement procedures. NBS' role is to help industry develop methods for accurate and reproducible NDE measurements. This includes technical investigations of standards, characterization of instruments, development of instruments and improved techniques, and the assessment of the meaning of the NDE measurement in relation to material performance. The main emphasis of the NBS program is on the needs for improved measurements and calibration standards and procedures for many of the NDE methods commonly used in industry.

At the Bureau, the NDE program is coordinated by the Institute for Materials Research. Strong interactions with industry, technical societies, and government agencies have been established in order to solicit their advice on needs and to aid in technology transfer for developed methods and standards.

Examples of NBS research in several areas of NDE are described below.

Acoustic-Ultrasonic Programs. Work is in progress to develop methods for calibration of ultrasonic and acoustic emission transducers. Spectral characteristics, beam profile, and total sound power measurements are being studied. Transducer calibration services are planned.

NBS researchers are studying ultrasonic test blocks in a program partially funded by the Air Force, Army, and the National Aeronautics and Space Administration to determine the reasons for variability of these metal calibration blocks. A calibrations service for aluminum ultrasonic tests blocks is available. Further directions for this effort include the development of material-independent test blocks and the development of well-characterized fatigue cracks that could serve as a calibration for many NDE tests.

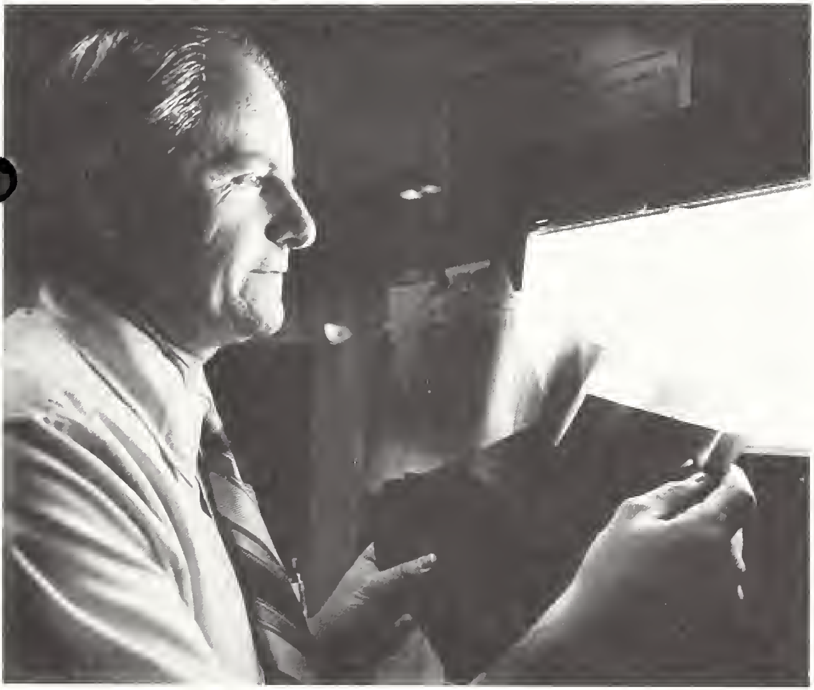
Instrumentation development work in both ultrasonics and acoustic emission is also in progress. This includes development of improved signal-to-noise ratio systems by methods such as signal averaging and pulse compression. A program to characterize the important variables in ultrasonic instrumentation has recently started. Imaging instrumentation is also under development.

These NDE methods are being applied to metals, ceramics, polymers, building materials, and electronic components. Specific application studies involving advanced ultrasonic instrumentation are also being conducted for the U.S. Nuclear Regulatory Commission (for steel reactor components) and the National Institutes of Health (ultrasonic diagnostic equipment for cancer detection).

A program to develop a theoretical basis for acoustic emission spectral analysis to characterize moving cracks or defects is in progress, partially funded by the Electric Power Research Institute. This program includes work for improved transducer calibration.

Radiography. Current programs involve work in both neutron and x-radiography. The x-ray program includes investigations of standards for the measurement of spatial resolution in radiographic systems and for the characterization of real-time fluoroscopic systems. Developments in progress include work in improved x-ray screens and grids and determination of scattered radiation content and its effect on radiographic detectors and systems.

The neutron radiographic studies are made primarily with a thermal neutron radiographic facility at the NBS research reactor. Work has been carried out with a 3 MeV Van de Graaff accelerator and a 100 MeV linear accelerator; a Californium-252 source is also available. A recommended practice for thermal neutron radiography is being developed in collaboration with the American Society for Testing and Materials. Standards for characterizing neutron beams for radiography and gaging are under investigation. In a collaborative program with Argonne National Laboratory, NBS scientists are investigating the use of three-dimensional thermal neutron radiography.



Neutron radiographs being placed for three-dimensional viewing.

Electromagnetic Methods.

- *Visual.* Under a program recently initiated, NBS scientists are examining methods for the measurement of visual acuity under typical NDE inspection conditions. This includes the effects of subdued lighting common in radiographic reading rooms and of the dark booth situations typically used in fluorescent penetrant and magnetic particle inspection.

The program will characterize test methods used in NDE where the human eye is an integral part of the system. Visual parameters critical to the ability of people to detect and judge visual indications of defects will be identified. These accomplishments will lead to recommendations for improved visual acuity measurement methods.

- *Electrical, Eddy-Currents.* Facilities for dc electrical conductivity measurements have been completed as the first stage of a new program in electrical and eddy-current methods. An ac conductivity measurement facility is also planned. In the future, work will include establishing measurement procedures for conductivity standards over the range of 1–100 percent of the International Annealed Copper Standard and methods for the calibration of eddy-current test equipment.

- *Microwave Methods.* Microwave measurements are being used to determine physical properties of materials. A new part of the NDE Program utilizes microwaves to measure moisture content of concrete. These measurements will be related to the strength of the material. This represents one area in which NDE methods are being explored for applications in the building industry. Future work to measure moisture content of other building materials is planned.

Penetrant Testing. NBS scientists are investigating the feasibility of preparing a master crack calibration plate for the evaluation of penetrant sensitivity. It is proposed to electrodeposit a heavy, non-adherent layer of nickel over a suitable crack plate and to use the removed nickel master to prepare duplicate calibration plates. It is known that this method will accurately reproduce crack dimensions as small as 3 μm wide by 3 μm deep. Methods for reproducing smaller dimensions are under study.

If the method proves useful, then the nickel master plate could be very well characterized. The calibration plates produced from it could be relatively inexpensive and could be discarded after some period of use. This would minimize problems presently encountered concerning the uncertainty of crack size due to crack growth and/or cleaning difficulties.

Wear Debris Analysis. Detection of worn metal in lubricants in mechanical machinery is now used in both military and civilian programs to determine the proper time for engine, bearing, and transmission overhaul. This method is now being expanded in a current NBS program, partially funded by the U.S. Navy, in which the wear debris particles in the lubricant are detected, sized, and examined in order to determine where and by what mechanism wear is occurring. Magnetic methods for obtaining size distributions of wear particles are used. X-ray microanalysis techniques have been developed for particles in the micrometer range. The techniques offer increased sensitivity for engine condition monitoring compared to conventional SOAP methods.

Thermal. This program is aimed at developing a method for the nondestructive evaluation of batteries used in critical assemblies such as cardiac pacemakers. A microcalorimeter capable of measurements in the 0.2 to 1000 microwatt range is used to measure heat generated in batteries and, in some cases, pacemakers, under a variety of conditions. Heat generation by new and partially discharged batteries is measured under no-load conditions as a measure of self-discharge. The work will be done in combination with other nondestructive and destructive tests and will result in a nondestructive method to determine power cell quality.

Additional information on NDE activities may be obtained from Program Manager, Nondestructive Evaluation Program, Institute for Materials Research, National Bureau of Standards, Washington, D.C. 20234; telephone (301) 921-3331.

COMPARISON OF COMMON NONDESTRUCTIVE EVALUATION METHODS

Method	Characteristics Detected	Advantages	Limitations	Sample
Ultrasonics	Changes in acoustic impedance caused by cracks, nonbonds, inclusions, or interfaces.	Can penetrate thick materials; excellent for crack detection; can be automated.	Requires coupling to material either by contact to surface or immersion in a fluid such as water.	Adhesive assemblies for bond integrity.
Radiography	Changes in density from voids, inclusions, material variations; placement of internal parts.	Can be used to inspect wide range of materials and thicknesses; versatile; film provides record of inspection.	Radiation safety requires precautions; expensive; detection of cracks can be difficult.	Pipeline welds for penetration, inclusions, voids.
Visual-Optical	Surface characteristics such as finish, scratches, cracks, or color; strain in transparent materials.	Often convenient; can be automated.	Can be applied only to surfaces, through surface openings, or to transparent material.	Paper for surface finish.
Eddy Currents	Changes in electrical conductivity caused by material variations, cracks, voids, or inclusions.	Readily automated; moderate cost.	Limited to electrically conducting materials; limited penetration depth.	Heat exchanger tubes for wall thinning and cracks.
Liquid Penetrant	Surface openings due to cracks, porosity, seams, or folds.	Inexpensive, easy to use, readily portable, sensitive to small surface flaws.	Flaw must be open to surface. Not useful on porous materials.	Turbine blades for surface cracks or porosity.
Magnetic Particles	Leakage magnetic flux caused by surface or near-surface cracks, voids, inclusions, material or geometry changes.	Inexpensive, sensitive both to surface and near-surface flaws.	Limited to ferromagnetic material; surface preparation and post-inspection demagnetization may be required.	Railroad wheels for cracks.

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